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Pioneer countries and the global diffusion of environmental innovations: Theses from the viewpoint of ecological modernisation theory

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ABSTRACT

This article examines how individual pioneer countries contribute to the development and global diffusion of technological environmental innovations. Key components to this end are stringent regulation, pioneer companies, and pacesetting lead markets. However, uneven development hinders the adoption of environmental innovations by less developed countries. This paper examines the subject from the viewpoint of ecological modernisation theory.

1. Introduction

This text deals with a number of rather complex questions concerning the theory and policies of ecological modernisation. It does so in a sequence of six theses. Thesis 1 starts from a core component of ecological modernisation theory regarding the pivotal role of technological innovation in changing the ecological properties of society's metabolism (Mol, 1995, pp. 27–59; Huber, 2004, pp. 21–58). The question then is how and by whom technological environmental innovations—TEIs, or eco-innovations, for short—are effectively developed and diffused.

I argue that the most important factors, or actors respectively, are regulation by nation–state governments (thesis 2) aimed at stimulating and backing eco-innovative activities of pioneer companies (theses 3 and 5), thus creating national lead markets (thesis 3). Global environmental governance, by contrast, so far has not proven to be a suitable point of departure for developing TEIs (thesis 4). Eco-innovations diffuse by domestic and global adoption (theses 3 and 4). The diffusion of innovative regulation and of TEIs within the world-system, however, meets with specific restrictions inherent in uneven development (thesis 6).

Each topic touched upon in the text is in itself rather complex. The purpose of this article, however, is to expound a coherent view of the development and global diffusion of TEIs, not least in order to establish strategic priorities for environmental policies aimed at ecological modernisation.

Thesis 1: The pivotal component of ecological modernisation is advanced technology

Modernisation refers to the dynamics of development and social change which characterise the transition from traditional to modern societies (cf. Harrison, 1991; Eisenstadt, 1987). The approach can be traced back to sociological classics such as Weber and Parsons, but also to Marx and neo-Marxist world-system theory (if stripped of purely ideological categories of *dependencia* theory such as mutually implied 'over- and under-development'). Sociological modernisation theory has been renewed under the headings of neo-modernisation or modernisation II (Tiryakian, 1991), and ongoing modernisation (Zapf, 1994).

Modernisation is a multifunctional process encompassing interrelated and co-directional cultural changes relating to religion, science, the arts, education, politics, and nation-building, as well as more instrumental functions such as state-building, lawmaking, and the development of markets, finance, industries and technology. Moving beyond its old-industrial stage, the modernisation of society now also entails ecological modernisation, i.e., readaptation of industrial society within the global geo- and biosphere *by modern means* such as a scientific knowledge base and advanced technology in order to upgrade the earth's carrying capacity and make development more sustainable.

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Saying that technological innovation is the pivotal component of ecological modernisation does not represent a technomaniac attitude. It simply reflects the fact that the locus within the functional structure of society where humankind actually metabolises with nature is the realm of industrial operations. Industrial operations include all activities of production and consumption carried out by technology-enhanced human work.

Environmental impact may have quite a number of social causes in addition to technology and the sheer size of population, e.g., consumerist attitudes, or lack of environmental awareness. But neither environmental ethics as such, nor regulatory measures nor economic mechanisms, will change the industrial metabolism unless they are geared to the unique point of immediate effect in changing society's metabolism: new *technologies and practices* that change the operative structures and ecological properties of production and consumption, and thus relieve strain on resources and environmental sinks or even contribute to an ecologically benign co-evolution of human society and nature. That is why technology, including technology-enhanced producer and consumer practices, is *as a matter of fact* the pivotal component of ecological modernisation.

Technology is not something detached from society. It is socially embedded and has its societal pre-conditions, so that understanding industrial change involves some degree of interdisciplinarity, as inherent in the approaches of socio-technical systems (cf. Mumford, 2003, 2006) and functional social-system analysis (cf. Sartorius and Zundel, 2005, pp. 10–49; Olsthoorn and Wieczorek, 2006; Huber, 2004, pp. 29–36, 200). According to the latter, technology and industrial operations of any kind are conditioned and controlled by co-related, co-directional impulses from different societal subsystems, particularly by the economy (markets and finance) as well as by public and business administration on the basis of law. Moreover, they are conditioned and controlled by formative impulses originating in politics, public opinion, knowledge base, values and life-styles. All of these subsystemic factors may analytically be treated as being separate from each other, whereas both historically and practically they have co-evolved in interdependency.

Technological environmental innovations exemplify 'greening strategies' such as: sustainable resource management, clean technologies, benign substitution of hazardous substances, bionics (biomimicry), product design for environment, product stewardship or extended producer responsibility, recycling, low-emission processes, and add-on purification technology in emissions control and waste processing.

Another way of deciding whether a technological innovation is also an environmental innovation is to determine whether a new technology contributes to significantly increased eco-efficiency and improved metabolic consistency. These terms are closely linked to sustainability discourse and the concept of industrial metabolism (Ayres and Ayres, 1996; Fischer-Kowalski, 1998; Fischer-Kowalski and Hüttler, 1999). Criticism of the shortcomings of the previous sustainability discourse has been a key element in more recent discourse on ecological modernisation with emphasis on innovation (Andersen and Massa, 2000; Mol and Sonnenfeld, 2000; Spaargaren et al., 2000; Sonnenfeld and Mol, 2002). This context provided the starting point for the concept of metabolic consistency (cf.; Huber, 2004, pp. 29–36) ometimes also referred to as eco-effectiveness (Braungart and McDonough, 2002, p. 103).

Metabolic consistency is about how to re-embed society's metabolism within nature's metabolism by introducing new technological regimes and practices which structurally change industrial operations and their metabolic *qualities*, rather than merely reduce the *quantity* of turnover within old structures. For example, energy demand on giga and tera levels may not be an ecological problem if it were clean energy. Currently, typical areas of TEIs include the following:

- regenerative, fuelless energy such as photovoltaics, wind, hydro, tidal, wave and undercurrent power, solar and, geothermal energy;
- substituting clean electrochemical fuel cells for pollutant furnaces and combustion engines in manifold applications, from power stations to vehicle propulsion;
- clean coal, notably in zero-emission central power plants on the basis of integrated gasifier combined cycle technology and carbon capture and storage. The dual purpose of these power plants can be to produce hydrogen and electricity at the same time;
- white transgenics[1], i.e., biochemistry making use of genetically modified enzymes and micro-organisms specially bred for various production tasks, replacing the conventional high-temperature high-pressure chemistry that poses a heavy burden on the environment;
- replacing hazardous chemicals by more benign low-impact substances;
- biofeedstocks partially replacing fossils as a raw material;
- new ultra-light, ultra-strong materials which reduce volumes of conventional materials and energy;
- nanotechnology and micromachines which cause less environmental impact as compared to larger conventional machines and chemical production;
- sonar, photonic and microfluidic analyses substituting for conventional methods involving hazardous ingredients, and improving quality and performance of production; and
- in agriculture, the introduction of sound ecological practices in combination with high-tech precision farming and green transgenics.

Such TEIs tend to upgrade efficiencies and be metabolically more consistent than previous technologies—although some new environmental problems might also have to be dealt with in the development of such innovations. It should be noted here that there is no such thing as an ecological standard metre, and that ecological fitness does not relate to a supposed 'natural state' of things. Ecological modernisation may sometimes coincide with nature conservation. More often, however, ecological modernisation is about changing, in fact developing the environment. Since humankind does this as a matter of fact, earth systems engineering and management, i.e., intentionally co-shaping geo- and bio-dynamics to the best of knowledge and belief, is a necessity rather than another fall from grace (Allenby, 2005).

Thesis 2: The most important pre-condition of eco-innovation is stringent regulation

The emergence of important new technological regimes is accompanied by lawmaking and regulation. It is stringent regulatory innovation which paves the way for TEIs. Empirical testing carried out by Esty and Porter reveals that stringency of environmental standards, sophistication of the regulatory structure, and strictness of regulatory enforcement are the most important factors for determining environmental performance (Esty and Porter, 2005, p. 412). Similar results are reported by

[1] 'White' transgenics refers to production in the chemical industry and materials processing. 'Grey' transgenics refers to add-on purification, site clean-up and mining technologies, 'green' transgenics to plants, 'red' to medical applications.

Jacob et al. (2005, p. 229). Among those who have stressed the importance of regulatory standard setting for environmental innovation before are Ashford (Ashford et al., 1985; Ashford, 2005) and Porter (Porter and van der Linde, 1995).

Regulation aimed at innovation tends to be different from a command-and-control type of regulation which typically entails cumbersome application procedures or even prescribes some best available technology which must be implemented. In certain cases, a command-and-control policy may be inevitable, but scholars who have explored the effects of regulation on innovation normally favour *performance standards*, in contrast to *best-available-technology standards* and *procedural standards* (Hemmelskamp et al., 2000). As Johnstone put it: 'while a technology-based standard will provide little incentive to innovate, a performance-based measure will provide strong incentives for innovation and diffusion of technologies which achieve given environmental standards at lower financial cost' (Johnstone, 2005, p. 22).

Performance standards can in certain cases be complemented by the push or pull of financial instruments such as green taxes, emissions trading (ET), or subsidies. Financial instruments, however, ought to be assessed case-by-case, because they are often reminiscent of a centrally planned economy. Calling them market-based instruments can be rather misleading. Environmental economists tend to agree upon the allocative efficiency and cost-effectiveness of economic instruments (Vos, 2005; Hansjürgens, 2005, p. 222). But they have yet to provide evidence of the attributable effects of such measures in developing TEIs (Neij and Astrand, 2006).

Moreover, stringent performance standards can be favourably complemented if put within a coherent framework of long-term policy goals (Jänicke and Weidner, 2002). Examples of this are national environmental plans (Jänicke and Jörgens, 1998) or the Dutch concept of transition management, a kind of strategic multilevel planning aimed at facilitating the transition from old-industrial technological regimes to eco-innovative regimes (Loorbach, 2007; Kemp and Loorbach, 2006).

Thesis 3: Environmental innovation takes place in lead markets of pioneer countries

Perhaps the most critical stage in the course of an innovation life cycle is that of market introduction. During this stage—when the transition from the engineering stage of research and development to regular production and use of a technology or product is made—an innovation needs the creation of a lead market. In most cases, a lead market is a national market, in some cases a world-regional market.

A lead market comes into existence where an innovation is successfully introduced into regular use for the first time on a large-enough and growing scale, thus defining what eventually can become the dominant design and the global standard when the innovation subsequently becomes internationally adopted (Beise and Rennings, 2005a, b; Jacob et al., 2005). Lead markets emerge in pioneer countries (Jänicke, 2005). There may be several countries and companies pioneering a new technology in an innovation contest. In both cases, main actors are progressive government, pioneering science and technology, and pioneer companies. For example, mobile telephony was first widely adopted in the Nordic countries, and Nordic companies served the first mobile-phone mass market there. US companies led the adoption of the personal computer. 'Penetration rates tend to be higher in the leading country for a considerable period of time, and this supplies firms with long-term user feedback and market knowledge which enables them to constantly improve the innovation and retain their lead' (Beise and Rennings, 2005a, p. 7).

With regard to environmental innovation, Japan, for example, was the lead market in desulphurisation technology in the 1970s. Denmark was the pioneer country and eventually became the lead market for wind turbines during the mid-1980s. A lead market may sometimes be shared as was the case with Japan closely followed by the USA as the lead markets for catalytic converters in motor cars in the 1970s. The USA and Germany were the lead markets for replacing phosphates with zeolites in detergents in the 1980s.

If a lead market is successfully set up, this demonstrates the advantages and practicability of an eco-innovation. Other countries will then consider adopting it. For example, Sweden and Finland have been the lead markets for chlorine-free pulping since the 1980s (Jacob et al., 2005, p. 45). Other industrial countries with pulp and paper industries, particularly the USA and Canada, also Austria and Germany, adopted the innovation within a couple of years, followed thereafter by Brazil and developing countries in South-East Asia (Sonnenfeld, 1999). Pioneer countries are found among advanced economies. Adopter markets were hitherto located in the triad North America–Western Europe–Japan. Now they increasingly include emerging economies.

Environmental innovations tend to be complex. Most often they require rearrangement of product chains, or even the setting up of new chains from scratch (as in the case of biofeedstocks, or fuel cells). Because of the complexities, and hence the risks involved, most industries shy away from TEIs in the first instance. That is why they need a reliable legal context which minimises economic risk, enables effective planning, and ensures fair competition. In addition, both companies and governments have usually needed a certain amount of pressure from environmental movements and public opinion to get kick-started.

Citizen initiatives and consumer organisations can in certain cases play an influential, if not always intentional, role in eco-innovation. In democracies, they influence government as well as corporate policies. Equally, end-user and consumer demand can have an important feedback effect on the development and diffusion of eco-innovative consumer items (Spaargaren, 2003; OECD, 2002). Because most Europeans, for example, are scared of transgenic food and therefore do not buy it, markets for such products have not so far developed. In contrast, a widespread preference for organic produce has resulted in strong growth of that line of agro-production (which, ironically, has resulted in imports from all over the world, because domestic producers prefer to grow subsidised fuel crops).

Consumer demand, however, neither invents nor produces supply items; its effect is *selective*. Producers may try to anticipate likely trends in consumer preferences, but consumers are not involved in setting up innovative technology life-cycles, nor are consumers, seen from a chain-analytical perspective, in the position of focal actors who have the means to influence an entire product chain, and who can thus implement effective chain management (Wolters, 2003; Seuring, 2004a, b). Normally, focal actors are large producers or retailers of end-products such as aircraft and car companies, oil companies, power stations, producers of detergents, paint, pharmaceuticals, office and household appliances, etc. These are the players who, to an important extent, simultaneously exercise demand-power upwards and supply-power downwards in the chains. To a certain extent, they thereby control supply-side push by technology developers, investors and producers as well as the choices available for meeting end-user demand.

Thesis 4: Despite globalisation, environmental policy and technological innovation remain dependent on individual pioneer countries. Global environmental regimes are rarely suitable points of departure for developing TEIs

The importance of *national* regulation and *national* lead markets does not seem to fit in with globalisation to the extent that this involves an ever growing number of agreements under international law, the integration of nations and companies into world trade, international manufacturing chains, cross-border R&D networks, and developments towards global multilevel governance (Held et al., 1999; Held and McGrew, 2003; de Prado, 2007). These trends of globalisation have led most scholars to posit a diminishing role for national government (Strange, 1996; Hardt and Negri, 2000), or even the obsolescence of national sovereignty and the nation–state (Ohmae, 1995; van Crefeld, 1999).

Globalisation trends have appeared so radical as to raise the question of whether globalisation marks a completely new structuration of the world-system or whether it represents another historical stage in the unfolding and upgrading thereof (discontinuist versus continuist interpretation according to Mol, 2001). This gives cause for pointing out that a discontinuist view appears to be contradictory to the model of ongoing, reflexive modernisation. The latter suggests rather the continuist view of globalisation as another stage of structural unfolding and upgrading in the development of the world-system. This is based on an understanding of continued change, which includes setbacks as well as patterns of recurrent crises, i.e., some degree of restructuring which has always occurred since the beginnings of the modern world-system around 1500. The question of whether economic globalisation and global governance today imply a reduced or a strengthened role for the nation–state has certainly not been given a final answer yet.

In accordance with the central role ascribed to the nation–state in modernisation theory (Eisenstadt and Rokkan, 1973; Flora et al., 1999), it is actually not difficult to draw together a number of obvious observations underpinning the continuist view:

- Global governance continues to rely on nation–states. International markets, chains, and networks are built upon the underlying frame of the world-system as a system of states. For simple functional reasons, industrial and civil-society organisations cannot be substitutes for state organisation. Effective governance ultimately relies on state prerogatives such as lawmaking, tax collection, and the use of force if necessary.
- Formal bodies of global governance such as UN-institutions (e.g., Security Council, WTO, IMF, World Bank) as well as semi-formal bodies such as the G8 and G20 actually accentuate national positions and strengthen the role of single governments by giving them a more formal international standing and thereby rendering their current status within the world-system more visible and explicit. As a result, global governance does not cause national governments to fade into the background, but brings them to the fore on a global scale. Global governance helps to co-ordinate and bundle the power of nation–states rather than diffuse and diminish it.
- Globalisation did not come about by chance, but was initiated by the world's leading national governments when they established international bodies and multilateral policy regimes aimed at cross-border exchanges, co-operation and development. This certainly complicates the business of national government. National rights and responsibilities become more differentiated, modifying the ways in which national sovereignty is exercised (Keohane, 2003; Litfin, 1998).
- Government activities are now more pervasive than ever, and government expenditure continues at high levels. Both regulation and money give a high degree of government influence over corporate and private actors.
- Nationalism is intensifying in newly industrialised and developing nation–states, and certain nation-centric political attitudes have of late also re-emerged in more advanced countries.
- Global governance bodies do not normally have supranational authority. Only very few global policy regimes as for example the WTO, have managed to become widely respected.

A partial exception to the non-existence of supranational authority is the European Union (EU). Eighty percent of regulation in agriculture and environmental policy, 65% in transport, 20% in work and welfare originates in Brussels, mostly in the form of EU-directives (Plehwe, 2007). So, there is an effective environmental policy within the EU, much as there is a common-market policy and a partial monetary union. To this extent, the EU can be seen as a part-federate umbrella-structure. In other policy fields, however, European lawmaking is next to non-existent, and the EU neither collects taxes nor does it command police and military forces.

- It is big nation–states which determine world politics (including UN politics, or NATO politics), particularly the USA, China, Russia, Japan, and an additional number of nation–states. Within this context, the EU aims at avoiding global marginalisation of its member states.

Similar observations apply to environmental policy and technological innovation. International environmental regimes have in no way reduced the importance of individual governments and national initiative. The Kyoto Protocol for limiting the emission of greenhouse gases (GHG) can be taken as an example. It represents a UN-organised multilevel approach to global environmental governance. Its impact, however, has so far been much more formative than effective. Sixteen years after adoption of the Framework Convention on Climate Change and 11 years after Kyoto, the Protocol is still not being supported by the newly industrialised and developing countries, neither has it been ratified by a number of advanced countries, and is being poorly implemented by those who did (McKibbin and Wilcoxen, 2002; Buchner et al., 2002; Cooper, 2001; Victor, 2001). Implementation deficits of international environmental agreements are notorious, not least because of unbalanced burden-sharing, too many countries opting out, and a lack of enforcement and sanctions (Najam et al., 2005).

Particularly uncertain are the effects of the Kyoto Protocol on eco-innovation. The protocol lacks an explicit innovation strategy (Guesnerie, 2003). It gives no idea of *how* to curb GHGs: whether by living on less (consumer sufficiency approach), by increasing eco-efficiency within existing product lines (which induces rebound growth rather than decreasing GHG emissions in absolute terms), or by improving metabolic consistency of production and products on the basis of TEIs.

The main policy instruments laid down in the Kyoto Protocol—emissions trading, joint implementation (JI), and clean development mechanism (CDM)—belong to the category of economic instruments which are thought to foster allocative efficiency, whereas their effect on technological innovation remains unclear. The questionable list of different national reduction targets agreed upon in the Kyoto Protocol does not represent general *performance standards*. For the time being, emissions trading under the Kyoto Protocol has been implemented in Europe only, and this was done in a counter-productive way in that too many emission rights were granted, given for free

(not auctioned), and too many exemptions allowed in order to avoid unfair non-EU competition. With regard to JI and CDM, the expectations arising from economists' model-worlds do so far not correspond to real-world experiences because of diverse political conditions and institutional arrangements (Larson and Breustedt, 2007; Chadwick, 2006).

Examples of global environmental agreements which made a tangible contribution to eco-innovation are rare. The Montreal Protocol on the ban of CFCs is one outstanding example. It has led to an ongoing substitution for such hazardous substances, and notwithstanding implementation deficits in the global East and South almost all developing countries have also become party to it (Wettestad, 1999, pp. 125–160). Another example is a decision taken in 2001 by the International Maritime Organisation to amend the Convention for the Prevention of Pollution from Ships. It requires newly built tankers to be double-hull ships; thereby actually adopting a piece of prior national legislation, i.e., the US Oil Pollution Act of 1990 in the aftermath of the Exxon Valdez catastrophe in 1989. While double-hull tankers are useful, they represent an incremental add-on measure and, rather than pointing the way forward, represent a way of avoiding path-changing innovation by adopting some defensive measure.

Aside from those rare cases, the effects, if any, of global environmental agreements on technological innovation remain hard to identify. The Rio process and UN-led conference processes in other policy fields undoubtedly contribute to developing international law, and they create some degree of common agenda setting. Multilateral environmental agreements can also contribute to clarifying national property rights, and standardise or ban certain practices in nature conservation and resource regimes (e.g., fishing quotas, ban of ivory trade, certified logging). Furthermore, national and international endeavours aimed at similar goals will of course benefit from each other. For example, it might strengthen international as well as national environmental policies if the WTO considered allowing for social and environmental criteria in its trading rules. But there is little support for a policy of sustainable global production and trade under the umbrella of the WTO. As Sonnenfeld and Mol (2002, p. 1457) put it in summarising a symposium on the subject: 'environmental governance still is very much linked to the effectiveness of nation–states'.

As a result, international environmental policy regimes are normally not a suitable point of departure for developing TEIs. Environmental standard setting will for the most part remain a national endeavour, which is particularly the case with regard to innovation-oriented policies. The future of eco-innovation continues to depend on the ability of individual national governments to prepare the ground for the emergence of a national lead market for a new technology which may stand the test of innovative competition and then eventually be adopted by other countries.

An example of this is Germany's Renewable Energy Sources Act: all electricity from any hydro, wind, solar, and biomass sources must at any time be bought by grid operators at a fixed price. The extent to which these sources really represent energies of the future remains to be seen, and the law resembles a centrally planned economy rather than an open-market approach (which is admittedly difficult in an oligopolistic sector). However, within the past few years, the law has stimulated manifold generic and incremental innovations in biomass, wind and solar power, and strong growth of national industries in the field. These are also expanding abroad, while foreign companies operating within the country equally profit from the boom. At the end of 2006, 47 countries had adopted the model. Another successful regulatory innovation is Japan's frontrunner approach, i.e., government-controlled benchmarking of fuel and electricity consumption, requiring the laggards to catch up with the leader within 5 years or face expulsion from the market. Again this is typical of centrally planned economy, but so far it has fostered energy efficiency in motors and electrical appliances.

Thesis 5: Internationally active companies are central to the creation and global diffusion of eco-innovations

While every innovation and lead market emerges under somewhat different circumstances, in-depth studies of lead markets have concluded that one decisive core component is always present: the interplay between performing companies and national government agencies on the basis of a clear policy agenda (Jacob et al., 2005, p. 229). Companies are key to environmental governance in that they are immediately part of the value chains and thus take the main decisions on whether and how to develop, produce, and use TEIs (Levy and Newell, 2005, p. 329). Transnational corporations as well as medium-sized internationally active companies are the most important operative agencies of pioneer countries.

Companies carry out the international diffusion of new technology by way of foreign sales, international co-production, joint ventures, cross-border R&D, outsourcing, subcontracting, and licensing (Giroud, 2003, p. 55). According to Baumol, these mechanisms ensure that 80% and more of the benefits of innovations are allotted to domestic and foreign partners, tax collectors, employees, and users, most of whom made no direct contribution to innovation, whereas the originator of an innovation appropriates about 20% of the benefits (Baumol, 2002, p. 121).

Many companies have now become 'world companies', i.e., the bigger part of their turnover and profits come from abroad as the majority of their jobs, and maybe even shareholders, are located abroad. Nevertheless, 'transnationals' retain a firm national embodiment. Although companies pursue particular business interests of their own rather than acting according to national interest, they have a home base with regard to headquarters, top management, business practices and corporate conduct (Hirst and Thompson, 1996; Doremus et al., 1998). Correspondingly, governments and public opinion consider TNCs to be 'national champions' belonging to a nation's assets.

The relationship between governments and companies keeps changing and there are temporary shifts in the balance of power (Held et al., 1999, p. 236). At present, e.g., increased cross-border factor mobility has exposed governments to intensified competition for attracting foreign direct investment (FDI), or keeping companies on location, by offering favourable business conditions such as low taxes, good infrastructure, and direct subsidies. For the time being, companies clearly have the whip hand in this area and governments have little choice but to accommodate. But even here, governments and companies rely on each other as they have done throughout the history of the modern world-system (Jones, 2005; Wilkins, 1998). They cannot take over each other's roles. TNCs' actions on the spot continue to be 'channelled and shaped by particular institutional arrangements and policy interventions' (Bairoch and Kozul-Wright, 1998, p. 63).

One should be aware of the fact that the scope of most 'global players' still is confined to advanced and newly industrialising countries. Even though FDI from emerging economies has of late risen strongly, 90% of FDI in triad countries still comes from other triad countries. Developing countries, in contrast, received only 16% of world FDI in 2005; yet China alone received another 12% (UNCTAD, 2006). As a result, 'global players' act as promoters of TEIs and technology transfer to the extent they deal with partners in advanced and newly industrialising countries. This is to a much lesser degree true, however, with regard to less developed regions.

Thesis 6: Environmental innovations do not easily trickle down the hierarchy of the world-system. Leapfrogging and tunnelling-through is possible, but limited

The main barrier to the transfer of technology from more to less developed countries consists of restrictions and incompatibilities caused by uneven development (Steinbach, 1999). In sociological modernisation theory, the notion of uneven development encompasses a broad range of factors, describing the transitional co-existence of obsolescent traditional elements, and modern elements on the rise in one nation, resulting in modernity differentials between progressive and conservative social milieus, advanced and backward sectors, centres and peripheries. The term is also applied to modernity differentials between nations at different general levels of development (MacKinnon and Cumbers, 2007).

In a recent model by Sachs (2003), the world-system is described as a three class model: first, there are the core innovators, representing the advanced nations; second, representing the emerging economies, the technological adopters, and diffusers who often also act as re-exporters, catching up through high growth rates; and third, the technologically excluded, representing less and least developed countries. The core innovator nations collectively are still home to 98% of the world's top-1000 technology companies, i.e., those that spend most on R&D and apply for most patents (OECD, 2006, p. 32). The core innovator nations still hold 94% of all patents issued each year whereas their share of the world population is 15%. The technological diffusers represent 65% of world population, the technologically excluded nations 20%. The latter may to a certain degree be users of advanced products and infrastructures, e.g., mobile telephony, or wells powered by solar panels. But they do not have the capacities to produce, much less to develop such goods and infrastructures themselves. The situation is certainly bound to change. Emerging economies, in addition to having become competitive producers, are rapidly building up R&D capacities of their own, e.g., in biotechnology where they hold a hitherto unusual number of patents. But newly industrialising and developing countries still have a long way to go in R&D.

Another model by Porter (2000, 1998) describes the issue from a different angle. According to Porter, industrial development proceeds through three stages: first, the factor-driven stage in which the economy is still labour-intensive and mainly produces basic goods from agriculture, forestry, and mining; second, the investment-driven stage, which creates growth by becoming ever more capital-intensive and building up mass-production industries, also including ever more complex products; third, the innovation-driven stage, where comparative advantages can no longer be realised by adopting, adapting, and catching up. Once a company or an entire nation joins the group of core innovators and operates at the cutting edge of the technological frontier, its future primarily depends on its endogenous ability to innovate (Açemoglu et al., 2002).

In view of the structural differences regarding the development stage of the nations in the world-system, eco-innovations and best environmental practices cannot be expected to spread from advanced lead markets immediately throughout the world. A country without sufficiently developed cultural and political coherence, institutional capacities, and especially, as Evans put it, without state–society synergy on the basis of developmental politics rather than predatory ones, will not be able to successfully adopt complex new technology (Evans, 1995). Development politics in the 1960s–1970s saw technology transfer not working under conditions of uneven development. One may remember the metaphor of 'cathedrals in the desert'. Despite impressive development successes in a number of world-regions in the past quarter-century, uneven development persists, though on generally upgraded levels. At present, eco-innovations and best practices can easily be adopted by nations in the league of core innovators, and they can now in many cases equally be adopted by today's emerging economies; but in most cases, not yet by less developed countries.

Today's emerging economies represent about two thirds of world population, and they now account for almost half of global GDP (IMF, 2007). Given their lower level of eco-efficiency, i.e., higher level of environmental intensity, they are bound to account for the bigger part of global resource consumption and emissions in the near future. As a consequence, it has become a necessity for newly industrialised countries to introduce resource and emissions-control regimes and adopt TEIs, and contribute to their advancement in the future—as they increasingly develop the capacities and acquire the means for doing so.

There has been a debate among environmental social-science scholars as to whether developing countries can benefit from technological leapfrogging and tunnelling-through. Leapfrogging means bypassing one or two generations of technology and directly skipping into the latest generation, e.g., mobile-phone networks without a previously installed full-scale fixed-line network, or adopting the electric arc furnace in steel industry, jumping the basic oxygen and the open hearth process. As a result of such leapfrogging, developing countries might be capable of tunnelling-through. The term is derived from the model of the inverted U-shaped environmental Kuznets curve (EKC). EKCs describe environmental intensity, i.e., resource consumption and pollution per unit product, as at first increasing, thereafter decreasing, in correspondence to development stage (Shafik and Bandyopadhyay, 1992; Selden and Song, 1994; Grossman and Krueger, 1995; Harbaugh et al., 2000). Countries which develop later might avoid climbing to old-industrial heights of resource consumption and pollution by 'tunnelling' through those old-industrial EKCs (Munasinghe, 1999; Goldemberg, 1998).

Real-world experience in emerging economies, however, is mixed (Ho, 2005, 2007). There are societal pre-conditions of leapfrogging and tunnelling-through, determining the extent and speed at which it can occur. For example, Asian emerging economies are at present experiencing a shortage of skilled workforce. Education and training takes time and effort. A country cannot 'tunnel through' the build-up of a modern mindset, a sufficiently coherent national identity, effective government and business management, a respectable legal and judicial system, middlingly efficient markets, monetary and financial institutions, general infrastructure, and professional and technological talent in sufficient numbers. Technological leapfrogging and tunnelling-through can only be done to the extent to which these necessary components of modernisation have been achieved (Perkins, 2003; World Bank, 2008, p. 51–92).

2. Conclusion

The main conclusion on the basis of the above theses is that national rather than global governance is most likely to lead to real progress regarding the development and diffusion of TEIs. The main actors in environmental innovation even in a globalising world are nation–state governments and nationally based pioneer industries rather than global bodies such as UN institutions, with the EU being a partial exception. The model of innovation and global diffusion is as follows: specific pieces of regulation and new technology are developed and implemented by one nation and nationally rooted industries, or a couple of nations and companies

in an international innovative contest, and are thereafter adopted by other nations who have the capacities and means to do so.

The larger part of the world has now developed the capacity for adopting advanced technology. Newly industrialising nations are increasingly building up-to-date production and research and development capacities of their own. The technologically excluded are becoming a minority in the world-system. Sustainable development on the basis of stringent, nationally-based performance standards and technological innovation may thus ultimately be achieved on a global scale. On the other hand, important TEIs, e.g., significant progress towards clean energy and vehicle propulsion, have repeatedly been delayed in present-day core innovator countries. This is to say that ecological modernisation takes more time than seems to be admissible in the face of the perceived problems of climate change, loss of biodiversity, freshwater shortage, desertification, etc. This raises the question of whether the pace of eco-innovative progress can match the current pace of environmental deterioration. It takes decades for both advanced and less developed countries to modernise and make substantial progress. Even the more advanced nations in the present world-system are in early rather than later stages of ecological modernisation.

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